Beaked Whale Workshop Summary

April 13-16, 2004
Baltimore, Maryland

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Introduction

The Marine Mammal Commission held a technical workshop on April 13-16, 2004, to explore issues related to the vulnerability of beaked whales to anthropogenic sound. The purpose of the workshop was to bring together scientists from a range of relevant disciplines to:

1) assess the most current knowledge of beaked whale biology and ecology and recent stranding events;
2) identify and characterize factors that may have caused the strandings; and
3) identify ways to more adequately investigate possible cause and effect relationships.

Thirty-one scientists participated in a process that included several presentations describing the most current information available on a series of topics, each followed by rich and productive discussions. Background papers had been prepared for each of the topics, which included:

- Acoustic Characteristics of Stranding Events
- Behavior and Ecology of Beaked Whales
- Distribution, Abundance, and Habitat
- Anatomy and Physiology
- Monitoring and Mitigation

Attendance at the workshop was also open to the public and approximately 50 observers attended, many of whom are also experts in related areas. Some of the observers provided presentations that added valuable information and insights to the discussions. Observers were provided an opportunity for public comment and questions each day.

Highlights of the workshop findings are summarized briefly below for the benefit of the Advisory Committee on Acoustic Impacts on Marine Mammals. This summary is not intended to be comprehensive but attempts to capture the general flavor and outcomes of the workshop. The Marine Mammal Commission will develop a more comprehensive report of the workshop proceedings and discussion. In addition, background papers prepared for the workshop will be published in a peer-reviewed journal.

Summary of Workshop Findings

Discussions at the workshop continue to support the assumption that beaked whales have unique characteristics that appear to make them particularly vulnerable to certain anthropogenic sound sources, including naval sonars and seismic activities. These characteristics are thought to be chiefly a function of habitat preferences, physiology and behavior. It appears less likely that the primary

vulnerability of beaked whales to anthropogenic sound is related directly to auditory system trauma. Rather, evidence suggests that the most likely mechanism of impact is linked to behavioral response and non-auditory, physical trauma.

The following findings received the most attention at the workshop:

1. Newly-described potential mechanism to explain the vulnerability of beaked whales to sound stimuli.

Workshop participants outlined a promising scenario describing a potential mechanism for beaked whale vulnerability to anthropogenic sound. Whereas other explanations and scenarios were not ruled out, this scenario was deemed particularly worthy of further exploration. Evidence presented at the workshop suggests that some beaked whales may be "saturation divers," spending most of their time at depth. Preliminary data suggest that at least some species of beaked whales have a dive profile not previously seen in other marine mammals. The critical components of this dive sequence include: 1) very deep and long foraging dives (to as deep as 1000 meters and lasting as long as 80 minutes), then 2) relatively slow, controlled ascents, followed by 3) a series of "bounce" dives to between 100 and 400 meters depth. Most other marine mammals are thought to "decompress" by spending extended periods recovering at the surface following deep dives. However, limited dive profile data from Cuvier's and Blainville's beaked whales do not show these times at the surface, despite deep, long dives. This suggests a unique dive behavior that raises the possibility that these whales may live in a physiologic condition of chronic supersaturation that would increase their susceptibility to gas bubble formation. This scenario emerged as links were made between pathology findings (including gas bubbles, fat emboli and acute, diffuse multi-organ hemorrhage) in fresh stranded beaked whales in the Canary Islands, dive profiles of beaked whales in the Mediterranean Sea and Canary Islands, comparisons with human diving physiology, and laboratory studies demonstrating immediate and acute bubble formation caused by application of an acoustic stimulus to gas-supersaturated fluids. These links were made possible only through exchanges among scientists of disparate disciplines, who seldom have the opportunity for such exchange.

2. Current mitigation efforts are ineffective in meeting protection requirements for beaked whales.

There are serious limitations in the effectiveness of management and mitigation approaches that rely on detecting beaked whales in areas of acoustic activity. Studies to examine the effectiveness of ship-based observations of beaked whales demonstrate that our ability to detect them, even under the best conditions, is very poor. Under typical mitigation scenarios, there is only a 1-2% likelihood of detecting a beaked whale. Even under the best conditions, highly controlled visual surveys produce only a 20-50% chance of detection. Key factors influencing mitigation effectiveness include sea state, daylight, experience of observers, and the diving behavior of beaked whales, which makes them unavailable for visual observation at the surface for long periods of time. These challenges in visual detection also contribute to the lack of adequate survey information on abundance, distribution and demographics of beaked whale populations, posing further problems for management and mitigation.

Results

Workshop participants identified a number of recommendations for moving forward to lay the foundation for informed management and mitigation decisions with regard to beaked whales and anthropogenic sound. The draft list of findings is attached (and will be further developed as the comprehensive workshop report is developed). The findings fall into the following categories:

Monitoring and Mitigation. In addition to concluding that existing mitigation methods that rely on visual detection of beaked whales are ineffective, the group identified both short term and long term monitoring and mitigation needs.

Communication and Education. Improved communication among scientists, the environmental NGO community, the general public, and policy makers was identified as an important need.

Coordination. Participants felt that there is much to be gained from greater coordination and collaboration among various players, particularly across scientific disciplines, between sound producers and stranding responders and researchers, and across international boundaries.

Research. The workshop participants developed an extensive list of research needs that reflects the paucity of data on beaked whales, the emergence of new ideas regarding the mechanisms for their vulnerability to sound, and other viable hypotheses. The list includes specific research needs in the areas of:

- Use of controlled exposure experiments to measure impacts of sounds on beaked whales;
- Behavior, especially dive behavior;
- Anatomy, physiology, and pathology (with priority emphasis on evaluation of the super-saturation hypothesis);
- Vocalizations (including development and validation of passive acoustic detection methods);
- Demography;
- Habitat modeling;
- Acoustic studies (identification of the types and characteristics of anthropogenic sound that may be relevant to beaked whale stranding events, empirical characterization of environmental parameters relevant to site/event-specific sound propagation, etc.); and
- Retrospective analyses of previous known stranding events (comparisons of pathology, sound exposure levels, habitat characteristics; documentation of sound sources during stranding events; etc.).

In particular, the group agreed on the following as the highest priorities for making meaningful progress:

1. There was unanimous support that controlled exposure experiments are the top research priority. These experiments should be used to gather critical information on beaked whale responses to sound. It was agreed that a workshop, involving scientists across several disciplines, should be held to coordinate and design controlled exposure experiments that would obtain the most useful information possible.

2. Participants agreed that there should be additional study of physiology, pathology, and anatomy of live and dead beaked whales (particularly in situations that may be related to sound exposure), as well as behavioral responses of live beaked whales to sound. There was strong support for developing a more comprehensive and internationally standardized protocol to make best possible use of animals that become available due to stranding or fisheries interactions. An informal sub-group was established to develop specific standard protocol components.

3. Researchers should conduct studies that increase our understanding of baseline diving behavior and physiology of beaked whales.

4. The scale of the existing problem needs to be addressed, via a retrospective review of all stranding records and the initiation of site-specific studies focused on beaked whale 'hotspots'.

Attachments

A. Workshop Participants
B. Workshop Agenda
C. Draft Outline of Workshop Findings

Beaked Whale Technical Workshop
April 13-16, 2004
Baltimore, Maryland

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Beaked Whale Technical Workshop
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Working Agenda

Goals of Workshop:

- assess current knowledge of beaked whale biology and ecology and recent stranding events;
- identify and characterize factors that may have caused those strandings; and
- identify ways to more adequately investigate possible cause-and-effect relationships.

Tuesday, April 13

9:00 – 9:30 Introductions/ Welcome

Acoustic Characteristics

9:30 – 10:15 Acoustic Characteristics of Stranding Events (Gerald D'Spain)

10:15 - 10:30 Break

10:30 – 12:00 Discussion

12:00 – 13:00 Lunch

Behavior and Ecology

13:00 – 13:20 Behavior/Ecology (Colin MacLeod)
13:20 – 13:50 Behavior/Ecology (Peter Tyack)

13:50 – 15:00 Discussion

15:00 – 15:15 Break

15:15 – 16:30 Discussion (cont'd)

16:30 – 17:00 Comments from the Audience

Wednesday, April 14

Distribution and Abundance

9:00 – 9:20 Distribution/Habitat (Colin MacLeod)
9:20 – 9:40 Abundance/Habitat (Jay Barlow)

9:40 – 10:20 Discussion

10:20 – 10:35 Break

10:35 – 12:00 Discussion (cont'd)

12:00 – 13:00 Lunch

Anatomy and Physiology

13:00 – 13:30 Anatomy/Physiology (Butch Rommel)

13:30 – 15:15 Discussion

15:15 – 15:30 Break

15:30 – 16:30 Discussion (cont'd)

16:30 – 17:00 Comments from the Audience

Thursday, April 15

Monitoring and Mitigation

9:00 – 9:30 Monitoring/Mitigation (Jay Barlow and Bob Gisiner)

9:30 – 10:30 Discussion

10:30 – 10:45 Break

10:45 – 12:00 Discussion (cont'd)

12:00 – 13:00 Lunch

Synthesis

13:00 – 14:45 Discussion

14:45 – 15:00 Break

15:00 – 16:30 Discussion (cont'd)

16:30 – 17:00 Comments from the Audience

Friday, April 16

Research Agenda

9:00 – 11:00 Discussion

11:00 – 12:00 Wrap-up

12:00 Adjourn

Draft Outline of Findings
MMC Beaked Whale Workshop
April 13-16, 2004

Monitoring and Mitigation

Current mitigation efforts (*i.e.* 1 observer on vessels searching in all sea states with low-powered (7x) binoculars and night vision detection at day and night) are ineffective (less than 1-2% chance of spotting a beaked whale) for beaked whales.

A. Long-term needs

Long-term studies of beaked whales will better inform monitoring and mitigation. These should include studies that

1. define population structure;
2. develop and test habitat models;
3. assess distribution and abundance;
4. assess population trends in local areas (*e.g.*, in Abaco, Bahamas); and
5. systematically collect information from live stranded and dead beaked whales.

B. Short-term needs

Short-term strategies should focus on detecting and evaluating impacts of anthropogenic sound activities on beaked whales. Mitigation and monitoring should include surveys for strandings and/or floating carcasses during and after anthropogenic sound activities. Concurrent with the mitigation and monitoring, there needs to be dedicated research to determine the probability of detecting a floating carcass. In addition, detailed analyses of monitoring should be conducted to determine if beaked whales are avoiding vessels. Finally, behavioral reactions of beaked whales during exposure to anthropogenic sources of sound should be monitored and analyzed.

Education

Workshop participants recommended that public outreach and education should be accomplished through various means, such as

1. improved communication with environmental non-governmental organizations;
2. established links among scientists, the public, and local and state policymakers; and
3. increased dissemination of stranding response information to the general public.

Coordination and Communication

Workshop participants identified a variety of areas in which improved coordination and communication are needed:

1. among stranding responders to develop an international standardized protocol;
2. among anthropogenic sound producers, stranding responders, and researchers in advance of a sound exposure event to facilitate responses and monitor animal behavior opportunistically;
3. between sound producers and researchers to conduct retrospective analyses;

4. among stranding responders to provide comprehensive databases to the public;
5. between scientists and museums to obtain genetic samples from museum collections to evaluate population structure; and
6. between terrestrial mammal physiologists and marine mammal scientists to establish formal links and increase understanding of beaked whale physiology.

Research

Workshop participants outlined a research agenda that will improve our understanding of why beaked whales appear to be more susceptible to anthropogenic sound activities than other marine mammals. The participants unanimously agreed that the highest priorities for research are:

1. controlled-exposure experiments to directly identify responses to received sound;
2. directed and opportunistic examination of the pathology, physiology, anatomy of live and dead beaked whales and behavioral responses of live beaked whales to sound;
3. modelling and experimentation to better understand dive behavior and physiology; and
4. determination of population-level significance and prevalence of sound exposure.

Participants also noted that broad participation across scientific disciplines (*e.g.*, human dive physiology, terrestrial mammalogy, marine mammal behavior, etc.) was a key to improved understanding and that broad research coordination and cooperation are needed.

A. Controlled Exposure Experiments

Workshop participants unanimously agreed that the highest priority should be placed on designing controlled exposure experiments to investigate responses of beaked whales to anthropogenic sound. By applying innovative technology, researchers can investigate behavioral and (as technology is developed) physiological responses to sound. The first step would involve a workshop to coordinate and design experiments that would obtain valuable information, yet not harm beaked whales.

B. Behavior

Workshop participants identified the need to conduct long-term studies on behavior of beaked whales to better define a baseline of what constitutes "normal" behavior. Obtaining baseline dive profiles via several methods over extended periods of time (e.g., D-tags, time-depth recorders, and visual observations) is especially important.

C. Vocalizations of beaked whales

Workshop participants recognized the importance of better identifying, classifying, and understanding vocalizations of beaked whales. For passive acoustic monitoring to be effective, researchers need to ground-truth detection methods by coupling visual and passive acoustic studies and by monitoring

vocalizations in areas for which we have good density estimates. In addition, researchers need to understand the behavioral context of vocalizations and develop and test detection algorithms.

D. Anatomy, Physiology, and Pathology

Many aspects of beaked whale anatomy and physiology need to be better understood to fully evaluate the various hypotheses as to why beaked whales appear to be more susceptible to anthropogenic sound activities. Workshop participants agreed that there was emerging evidence to support the hypothesis that beaked whale tissues may often be supersaturated with nitrogen, and the whales may therefore have unique physiological responses to changes in dive profile or exposure to intense sound. To better evaluate that hypothesis, participants identified three aspects of beaked whale biology that need to be evaluated:

1. physiological effects of dive profile (and subsequent implications for tissue supersaturation); which includes onset and effects of lung collapse; and
2. potential for acoustically facilitated bubble nucleation and/or growth.

In addition, participants identified several other aspects of pathology and physiology that need investigation, including:

1. understanding gross and microscopic anatomy of both healthy and pathological beaked whale carcasses;
2. standardizing gross and histopathological examinations of all beaked whale strandings, with special emphasis on gas and fat emboli;
3. investigating direct acoustic impacts on tissue;
4. determining the reaction of the vestibular system to acoustic stimulation;
5. characterizing blood flow patterns (*e.g.*, determining the amount of gas and blood flow through the venous plexus surrounding tissues and through Eustachian tubes);
6. investigating blood properties of beaked whales;
7. collecting baseline data on hearing and anatomical sound propagation in beaked whales to understand physiological and behavioral responses to sound; and
8. investigating movement (vertical and horizontal) of carcasses and the ability to detect them to inform development of management strategies.

Workshop participants discussed the importance of better coordination of prioritizing research and access to tissues, possibly via tissue banks/archives. They also recognized the potential utility of using surrogate species (*e.g., Kogia* or *Tursiops*) in research and comparing results among various beaked whale species. Finally, participants agreed that when possible, attempts should be made to rehabilitate live stranded beaked whales and, in the process, take advantage of live beaked whales in opportunistic studies.

E. Demography

Understanding demography (*e.g.*, distribution, abundance, life history, etc.) is critical to evaluating the impacts of anthropogenic sound activities on beaked whales. Workshop participants identified the following information needs and methods to gain that information:

1. Species and population structure should be investigated, possibly by a dedicated effort to obtain specimens globally from museums.
2. Distribution needs to be better defined for all species of beaked whales and some data could be acquired by placing trained observers on platforms of opportunity (*e.g.* whale watch vessels, cruise ships, ferries, transiting seismic vessels, etc.).
3. Abundance and density need to be estimated, especially in those areas where species are most at risk. Systematic surveys should include collection of oceanographic data to help identify key habitat characteristics.
4. Movement patterns need to be understood and should be studied via various methods (*e.g.*, stable isotope ratios and telemetry).
5. Our baseline understanding of life history, including age and sex structure and geographic variation in length distributions, needs to be improved.
6. Some of the research needs can be accomplished through long-term photo-identification studies.

F. Habitat Modelling

Habitat modelling can improve our understanding of basic beaked whale biology, and may help managers and sound-producers predict areas with high beaked whale densities. However, workshop participants suggested a cautious approach in extrapolating habitat models to different areas, because of documented differences between ocean basins.

G. Acoustic Studies

Workshop participants recognized the importance of:

1. identifying key characteristics of sound (*e.g.*, frequency, amplitude, energy, directional transmission pattern, etc.) that may be important to beaked whales;
2. identifying characteristics of anthropogenic sounds relevant to historic stranding events;
3. determining bounds on received sound levels prior to stranding to evaluate viability of some hypotheses attributing pathologies to direct effects of sound;
4. site-specific modelling (post-hoc and predictive) of sound propagation, especially in cases when detailed environmental data are not available; and
5. empirically characterizing environmental parameters that influence sound propagation by developing statistical approaches to incorporate data scarcity.

H. Retrospective analyses

Workshop participants believed that retrospective analyses would help inform the context in which beaked whales appear to be more susceptible to anthropogenic sound events and the extent of the problem. These analyses would include the following:

1. describe and compare pathologies from all stranding events, including those with known absence and presence of anthropogenic sources;
2. model the sound exposure levels at a modeled receiver throughout the water column across sites with known stranding events;
3. document all anthropogenic sound sources during stranding events;
4. determine if there have been population effects in those areas for which there are long-term data (*e.g.*, photo-id in Bahamas);
5. evaluate distribution of both mass and single strandings in terms of topographic relief and in relation to anthropogenic sound activities; and
6. determine if there are areas of known beaked whale distribution where there have not been documented mass strandings but there have been documented naval exercises (*e.g.*, Scotland) and compare those with areas of known stranding events in relation to anthropogenic sound events.